Computational Modeling of Visual Search Behavior

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Abstract*— Humans often perform risk-sensitive decision tasks that require simultaneous visual processing and high-level cognitive integration of complex visual information such as physicians reviewing multiple medical images per patient. To maximize human performance, intelligent user interfaces and decision support systems must be developed to account for the individual's perceptual and cognitive limitations to effectively synthesize rich visual content in a time-efficient manner. Eye-tracking technology with sophisticated data analytics is critical for understanding the association between visual perception and cognitive error, particularly when humans are asked to process high volumes of complex visual data. Traditional eye gaze pattern analysis studies are based on eye gaze fixation and dwell time to derive group-based understanding of human visual search behavior. We have been developing novel methods to capture the spatiotemporal characteristics of human visual search based on hidden Markov models, shapelet analysis, fractal analysis, and machine learning methods. We will demonstrate the application of these methods on a clinical application; namely breast cancer screening. Eye-tracking data and diagnostic decisions were collected from 10 readers (three board certified radiologists and seven radiology residents) viewing 100 mammographic cases (25 normal, 25 benign, 50 malignant) without prior knowledge of the cases. The visual search task involved simultaneous viewing of four coordinated breast views as typically done in clinical practice. The readers' visual search scanpath was modeled using hidden Markov models, shapelet, fractal analysis, and machine learning methods including deep learning. The purpose of the analysis was to understand (i) how each method captures different aspects of the human visuo-cognitive process (visual search complexity vs. human performance) as well as (ii) whether each method can be leveraged as the basis for gaze based biometrics. Our results suggest that all methods are effective in modeling human visual search but model accuracy depends on both image and reader characteristics.

Keywords—eye-tracking; visual search; perceptual modeling; decision making